

RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #4

**Proposed Appendix M to the 1090 MHz ADS-B MOPS
To Define Extended Range Reception Techniques**

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SUMMARY
The attachment to this working paper was prepared in response to Action Item 2-4, which was accepted at the Feb. 2001 meeting of WG3, in Melbourne, FL. It is proposed that WG3 accept the attached draft of Appendix M, and further develop this material for inclusion into Revision A to the 1090 MHz ADS-B MOPS.

Appendix M

Extended Range Reception Techniques

***** *DRAFT Revised 5/15/2001* *****

M.1 Purpose and Scope

The purpose of this appendix is to provide a description of techniques for extending the air-to-air reception range of extended squitters. Two techniques are explored: (1) use of a directional antenna for 1090 MHz extended squitter reception; and (2) optimized 1090 MHz ADS-B reception extended by employing a variable bandwidth receiver to provide improved reception sensitivity under low-to-moderate 1090 MHz fruit conditions.

M.2 Background

The ADS-B MASPS, DO-242, specifies the required air-to-air reception range for a number of ADS-B applications. The application identified with the longest reception range requirement is the flight path de-confliction application. The reception range requirements associated with this application are asymmetric as a function of target bearing from the receiving aircraft. Specifically:

- 90 NM required, 120 NM desired in the forward direction
- 45 NM toward the port and starboard
- 30 NM toward the aft

DO-242 defines the flight path de-confliction application as being applicable to “cooperative separation in oceanic/low density en route airspace.” Thus as currently defined by the ADS-B MASPS this application is not required to be supported in moderate to high traffic density en route or terminal airspace. However, some aviation organizations, including Eurocontrol, have identified the potential need for a flight path de-confliction application that could be used by high altitude en route aircraft over flying airspace with moderate to high traffic densities. Furthermore, it has been suggested that the desired reception range be extended to 150 NM. Although RTCA has not accepted changes to the ADS-B MASPS that would impose such enhanced ADS-B reception capabilities as explicit requirements on ADS-B systems, additional optimizations in the design of airborne extended squitter systems may prove useful in satisfying the requirements associated of future ADS-B applications.

The maximum air-to-air reception range requirement associated with the other ADS-B applications defined by DO-242 is 40 NM, without any target bearing dependency. Thus an ADS-B intended to support all of the applications defined by DO-242 supports reception ranges of 90 NM forward, 45 NM toward the port and starboard, and 40 NM to the aft, in low traffic density airspace. For high traffic density airspace the required reception is 40 NM from any direction.

M.3 Current Reception Range

The most capable class of ADS-B receiver specified by these MOPS is for Receiver Class A3 (Extended Capability). This receiver class is specified to have an MTL of -84 dBm and when used in conjunction with omni-directional diversity aircraft antennas is intended to satisfy the requirement of DO-242 for an air-to-air reception range of 90 NM. This assumes all of the target aircraft of interest at the maximum range are equipped with Transmitter Class A3 with a minimum transmit power (at the antenna port) of 250 watts. The 90 NM reception range capability is thus focused on users operating in high altitude en route airspace where the most capable class of avionics would be applicable.

M.4 Enhanced Reception Range Techniques

The focus of this appendix is on detailing techniques to provide for extended reception range (i.e., beyond 90 NM) in the forward direction, especially in low to moderate 1090 MHz fruit environments. These techniques apply to receivers and antennas not shared with TCAS as they employ antennas and receivers that are optimized solely for the reception of extended squitters in support of the ADS-B function. The described techniques for enhanced reception range apply to Class A3+ receivers (i.e., Class A3 receivers that have also implemented the improved reception techniques specified in section 2.2.4.4 of these MOPS). Further, these techniques apply only to extending the ADS-B reception range between aircraft operating in high altitude en route or oceanic airspace.

M.4.1 Optimized Receive Antenna Configurations

One technique for support an enhanced extended squitter reception range would be the provision of aircraft antennas with antenna patterns and gain characteristics that are optimized for the ADS-B system performance requirements, as summarized in subparagraph M.2. The baseline aircraft antenna configuration applicable Class A3 ADS-B avionics is assumed to employ omni-directional top and bottom diversity antennas and to be consistent with characteristics described in Appendix C. A more optimum aircraft antenna configuration is possible that is optimized specifically for the reception of extended squitters at the maximum range in the forward direction. Such an optimized aircraft antenna configuration must still support reception at the ranges required by DO-242 non-forward directions and must also not degrade reception performance in moderate and high 1090 MHz fruit environments. Two candidate optimized aircraft antenna configurations are described below that satisfy these constraints.

M.4.1.1 Aircraft Antenna with Enhanced Forward Gain

In this configuration the bottom aircraft antenna has antenna pattern characteristics as in the baseline configuration (i.e., omni-directional). However, the baseline configuration's single element omni-directional top aircraft antenna is replaced with a two-element directional antenna providing 3 dB of additional gain in the forward direction. The typical configurations of the top and bottom aircraft antennas are summarized below:

Top Antenna:

- employs one driven quarter wavelength element and one or two passive elements. The elements are tuned to provide peak gain and minimum VSWR at 1090 MHz. and providing +4.5 to +6 dBi nominal gain in the forward direction (exclusive of any internal amplification), as compared to the baseline omni-directional antenna which provides a nominal 3 dBi gain.
- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure of **TBD** at 1090 MHz.

Bottom Antenna:

- omni-directional antenna employing a single quarter wavelength element tuned to provide peak nominal gain of +3 dBi (exclusive of any internal amplification) and minimum VSWR at 1090 MHz).

- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure of ***TBD*** at 1090 MHz.

M.4.1.2 Aircraft Antenna with Increased Vertical Aperture and Enhanced Forward Gain

In this configuration the bottom aircraft antenna has antenna pattern characteristics as in the baseline configuration (i.e., omni-directional). However, the baseline configuration's single element omni-directional top aircraft antenna is replaced with a multi-element directional antenna providing 4 to 6 dB (nominal) of additional gain in the horizontal plane in the forward direction. The typical configuration of the top and bottom aircraft antennas are summarized below:

Top Antenna:

- employs two driven quarter wavelength elements stacked vertically with 2 or more passive elements. The elements are tuned to provide peak gain and minimum VSWR at 1090 MHz. and providing +7 to +9 dBi nominal gain (exclusive of any internal amplification) in the horizontal plane in the forward direction, as compared to the baseline omni-directional antenna which provides a nominal 3 dBi gain.
- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure of ***TBD*** at 1090 MHz..

Bottom Antenna:

- omni-directional antenna employing a single quarter wavelength element tuned to provide peak gain of +3 dBi (exclusive of any internal amplification) and minimum VSWR at 1090 MHz).
- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure of ***TBD*** at 1090 MHz.

M.4.2 Dynamic Bandwidth Control

Class A3 receivers, not shared with TCAS, are specified to have an MTL (at the antenna) of -84 dBm (see Table 2-62). The out-of-band rejection for a message frequency difference of ± 5.5 MHz is specified in Table 2-63 to be at least 3 dB above this MTL. These out-of-band rejection characteristics correspond to a receiver design that employs intermediate frequency (IF) filtering with an effective bandwidth of approximately 8 MHz. Modeling of the enhanced decoding techniques defined in section 2.2.4.4 of these MOPS has shown that reducing the IF bandwidth to significantly less than 8 MHz (e.g., 4 MHz) can degrade the decoder performance, when using the enhanced decoding techniques, thus degrading the overall reception performance in high 1090 MHz fruit environments. However, such a reduction in the IF bandwidth has also been shown to allow for decreased receiver MTL values resulting in improved reception range when used in low-to-moderate 1090 MHz fruit environments. An optimum design for a dedicated 1090 MHz ADS-B receiver would provide for a mechanism to dynamically reduce the IF bandwidth, thus supporting increased receiver sensitivity, when operating in a low-to-moderate 1090 MHz fruit environment.

The technique described here requires a 1090 MHz receiver design capable of varying the receiver sensitivity and out-of-band rejection characteristics as a function of the 1090 MHz fruit

levels. This could be implemented either as a process capable of continuously varying the IF bandwidth over an allowed range or as a simple two-step approach (full or reduced IF bandwidth), as assumed below. It cannot be expected that RF fruit levels will be directly measured by 1090 MHz ADS-B receivers. Therefore, monitoring of the percentage of low confidence bits declared by the decoder over a fixed time interval will be used as the measure for selecting the appropriate MTL and out-of-band rejection characteristics (i.e., selecting the effective IF bandwidth). Specifically, the out-of-band rejection characteristics will be as listed in Table 2.63 (with an MTL of -84 dBm) for the case where the measured percentage of low confidence bits declared over ***TBD*** seconds is greater than ***TBD*** percent. However for the case where the measured percentage of low confidence bits declared over ***TBD*** seconds is less than or equal to ***TBD*** percent, the nominal receiver sensitivity is increased to a MTL of - 87 dBm (at the antenna) and the out-of-band rejection characteristics are as defined in Table M-1 below (implying a reduced effective IF bandwidth).

Table M-1: ADS-B Receiver Out-of-Band Rejection for Extended Reception Range Technique

Message Frequency Difference (MHz. from 1090 MHz.)	Triggering Level (dB above -87 dBm)
$\pm 4^*$	Greater Than –or- Equal to 3
$\pm 8^*$	Greater Than –or- Equal to 20
$\pm 12^*$	Greater Than –or- Equal to 40
$\pm 22^*$	Greater Than –or- Equal to 60

<<<< * *Editor's Note: Need to determine validate correct values* >>>>